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Windshields for Precipitation Gauges and Improved Measurement Techniques for Snowfall

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The chemistry of snow water is measured by accurately collecting snowfall amounts and analyzing the snow that has been melted—usually in a glycol mixture. The problem with current snow measurement techniques is that with almost any wind, collection efficiency is questionable, leading to large uncertainties in estimates of pollutant concentration. Most current combinations of windshields and gauges are ineffective, requiring the gauges to be maintained and monitored frequently.

The issue of measuring snow and frozen precipitation in windy situations has been heavily researched. While many gauges and windshields have been developed and tested during the last 150 years, no combination of windshield and gauge has 100-percent catch efficiency in all wind events. The World Meteorological Organization (WMO) has organized three international intercomparisons of gauges and windshields since 1959, the most recent including data collected from 1985 to 1998. The National Center for Atmospheric Research (NCAR) recently completed a study at the Marshall Field site (Rasmussen and others. 2001. Bulletin of the American Meteorological Society. 82: 4. p. 579–595).

Snow Gauges

Snow gauges range from rudimentary buckets to ultrasonic depth sensors. Heated buckets that tipped to pour out water were once the most prevalent gauge, but they were inaccurate. These gauges were developed to collect rainfall before being modified for snow. They never performed well. A heating element was added to the gauge to melt the snow, but evaporation loss became a major factor. Catch efficiency for a heated tipping bucket averages only 35 percent for frozen precipitation.

Alter windshield.

Most modern gauges now contain a glycol solution or antifreeze topped with a thin film of low-viscosity oil. The glycol solution melts the snow and the oil reduces evaporation loss. The water measurements are taken manually or transmitted by radio signal, depending on the sophistication of the particular gauge. Although many manufacturers produce these gauges (ETI, Belfort, Campbell, and others), meteorologists in Canada and the United States are leaning toward the Geonor precipitation gauge.

The Geonor vibrating-wire precipitation gauge uses a bucket suspended by wires. Glycol solution is in the bucket. As snow falls and melts in the glycol solution, the mass increases. The wires stretch and begin to vibrate, producing an electromagnetic field that is picked up by the bucket's sensor. The strength of the electromagnetic field depends on the mass in the bucket, allowing the contents to be measured accurately.

Manufacturers boast superior catch efficiency, yet all contend that wind remains the largest problem. These gauges are nearly worthless without a windshield and must be sited in areas sheltered from the wind.

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Windshields

The Double Fence Intercomparison Reference gauge (DFIR, figure 1) was used as a standard for all other windshields in the WMO's intercomparison study and at the Marshall Field site study. The DFIR consists of two fences, one 4 meters in diameter and the other 12 meters in diameter, circling a Tretyakov or Geonor gauge. For the Marshall Field site study, the Geonor gauge was used almost exclusively. This system's catch as a function of windspeed has consistently proven to be 92 to 96 percent of the actual snowfall in most wind events. Unfortunately, the sheer size of the system limits its placement.

Figure 1—The double fence intercomparison reference gauge catches 92 to 96 percent of the precipitation that falls.

At the Marshall Field site a small DFIR was tested as an alternative to the larger one. The small DFIR is about two-thirds the size of the regular DFIR. The small DFIR still caught 80 to 90 percent as much precipitation as the large DFIR with winds of about 6 meters per second.

For Canadian systems, the Nipher shield has long been the standard. It is a solid shield made from spun aluminum, plastic, or fiberglass in the shape of an inverted bell. Because of its solid construction, this shield tends to bridge over with snow if it is not frequently checked. This problem usually leads to precipitation overcatch. As temperatures warm, snow dumps into the gauge, which can cause problems with real-time measurements. Despite these problems, a well-maintained gauge, surrounded by a Nipher shield, has an average catch of around 90 percent of the DFIR at gauge height windspeeds of 4 meters per second. The catch falls to 60 percent of the DFIR at windspeeds above 8 meters per second.

Alter shields (figure 2) are the most common windshield in the United States, even though their efficiency is low. An Alter shield is a ring of vertically oriented slats with a radius of about 0.5 meter. Gauges equipped with Alter shields rely heavily on proper site placement to reduce the effects of wind. The catch efficiency for a Geonor gauge surrounded by an Alter shield drops to around 60 percent of the DFIR with winds of 5 meters per second, but falls to 15 to

Figure 2—The Alter windshield catches little of the precipitation that falls during high winds.

20 percent of the DFIR with winds of 8 meters per second.

A double Alter shield was tested at the Marshall Field site. The double Alter shield (figure 3) has another ring of vertically oriented slats 0.5 meter from the inner ring. This system offers a significant improvement over the single Alter shield. Catch efficiency for a Geonor gauge within a double Alter shield is over 85 percent of the DFIR for windspeeds as high as 6 meters per second and may be as much as 80 percent of the DFIR for windspeeds of 10 meters per second.

Wyoming windshields were also tested at the Marshall Field site. A Wyoming shield consists of two mesh fences slanting outward at the top. The outer fence is 20 feet in diameter. The catch efficiency for a Geonor gauge in the Wyoming shield decreased rapidly at windspeeds higher than 4 meters per second. A catch of about 50 percent of the DFIR was recorded at wind speeds of about 8 meters per second.

A half-scale Wyoming shield (figure 4) was developed by Roy Rasmussen and others for the Marshall Field site study. Catch efficiency for a Geonor gauge in a small Wyoming shield is less than 50 percent of the DFIR in winds higher than 5 meters per second. Catch efficiency continues to drop to around 10 percent of the DFIR at windspeeds of 8 meters per second.

Various other shields have been tested and compared, with poor results. Many are slight modifications of the popular shields and offer no

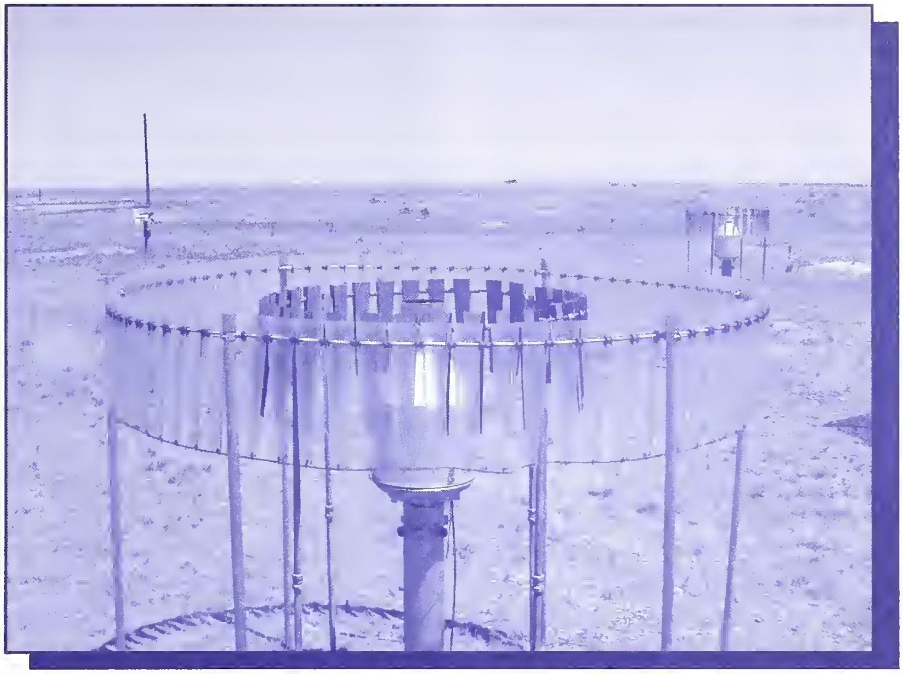

Figure 3—The double Alter windshield performs well in high winds.

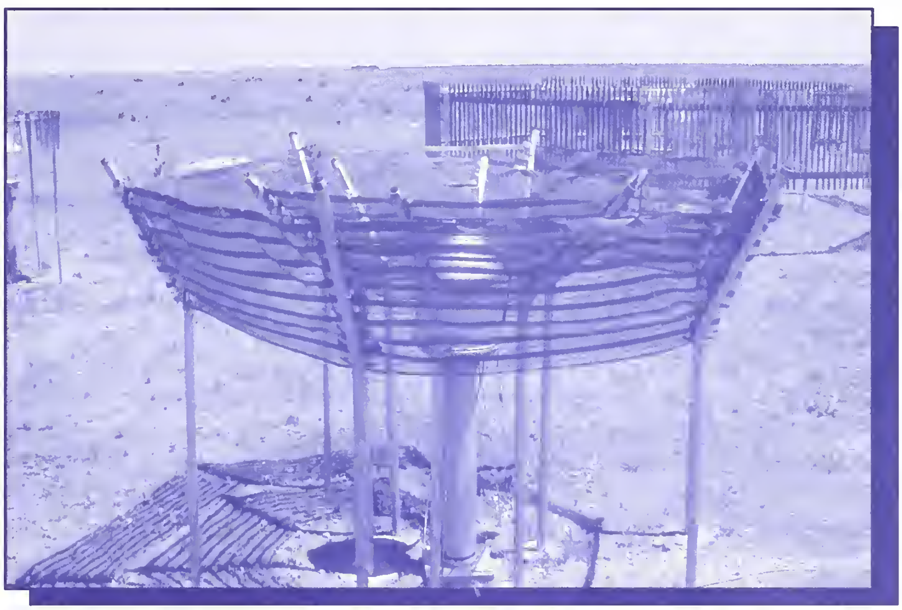

Figure 4—The catch efficiency for the half-scale Wyoming windshield drops rapidly as wind increases.

significant improvements. Researchers have produced algorithms intended to compensate for variables when using current gauges. These algorithms can be found in: 'WMO Solid Precipitation Measurement Intercomparison: Final Report' (Goodison, B.E.; Lonie, P.Y.T; Yang, D. 1998. Instrument and Observing Methods Report No. 67. WMO/TD No. 872. 88 p. + 211 p. annexes).

Figure 5—The hotplate snow gauge does not require a windshield.

New Gauges

Some researchers have begun to abandon the windshield and bucket-type gauge altogether. The general consensus is that it is impossible to create a shield/gauge combination with 100-percent catch efficiency in all wind events. Researchers have decided that since wind cannot be controlled, it needs to be eliminated as a factor. Some innovative ideas have resulted.

The hotplate snow gauge (figure 5) consists of two heated metal plates. One plate faces up, exposing it to precipitation, and the other, just below the top plate, faces down. The plates are heated to an identical temperature. Any precipitation landing on and evaporating off of the gauge cools the top plate. The energy used to maintain the temperature of the top plate is compared to the energy used to heat the bottom plate. Because the bottom plate is not exposed to the precipitation, it is used as a reference.

This snow gauge is still in the testing process, but shows promise. It is inexpensive and easy to maintain. It does require power, so wilderness applications could be limited. It does not collect the precipitation that it measures, which means that it could not be used to gather samples for chemical evaluation. The hotplate gauge may become commercially available.

The Eastern Cereal and Oilseed Research Centre in Ottawa, ON, has also developed a gauge that requires no windshield (figure 6). It consists of a revolving ball, half submerged in a catchment area full of automotive

Figure 6—This Canadian rotating ball gauge does not require a windshield.

antifreeze. As the ball rotates, it is wetted in the antifreeze to improve catch efficiency. A pump and reservoir maintain the level of liquid to prevent evaporation loss. Because this device does not rely on a bucket-shaped catch area, it does not require a windshield. This gauge can be equipped with a data logger and is battery powered. No data were available for catch efficiency, although the inventors claim that it compares well with the Nipher shield and gauge. The inventors are still looking for a manufacturer. Canadian (2,147,700) and United States (5,571,963) patents have been granted.

Site Selection

Site selection is a major factor in the effectiveness of a precipitation gauge. Most remote weather stations must be exposed to the elements, so the precipitation gauge must be exposed to wind. One potential solution is to separate the precipitation gauge from the weather station so a more sheltered site can be selected for the precipitation gauge. This technique can be costly, but if the precipitation gauge is properly sited, measurements can be much more accurate.

A precipitation gauge should be placed in a level, open clearing in the trees. No vegetation should be above the level of the gauge. The distance of the gauge to the trees should roughly equal the height of the trees. In other words, an angle of roughly 40 to 45 degrees from the gauge's orifice to the tops of the surrounding trees is ideal.

Conclusions

While major steps are being taken to solve the problem of the effects of wind on precipitation measurements, the only solution that is universally approved is the DFIR. The larger fence for the DFIR is 12 meters in diameter, making this windshield impractical in some situations. The alternative windshields described in this Tech Tip are readily available or easily constructed. Finding a reasonably accurate combination of windshield and gauge is possible for most applications, even though a universal solution is not available.

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Library Card

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Describes the results of several studies that have shown that most windshields used with precipitation gauges are not very effective. The standard by which windshields are measured is the double fence inter-comparison reference gauge. That windshield consists of two fences. The inner fence is 4 meters in diameter. The outer fence is 12 meters in diameter. Other windshields that are discussed include the Nipher shield, the Alter shield, and the Wyoming shield. The gauge that seems to be the most popular for measuring snowfall in Canada and the United States is the Geonor precipitation gauge. Glycol solution is in a bucket that is suspended by wires. As snow falls and melts in the glycol solution, the mass increases. The wires stretch and begin to vibrate, producing an electromagnetic field that is picked up by the bucket's sensor. The strength of the electromagnetic field depends on the mass in the bucket, allowing the contents to be measured accurately.

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